USDA FOREST SERVICE RESEARCH PAPER PNW-228
1977

Effects of AERIAL APPLICATION OF DDT on Reproduction in House Wrens and Mountain and Western Bluebirds

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FOREST SERVICE
PORTLAND, OREGON

Contents

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Effects of Aerial Application of DDT on Reproduction in House Wrens and Mountain and Western Bluebirds

Reference Abstract

McCluskey, D. Calvin, Jack Ward Thomas, and E. Charles Meslow.
1977. Effects of aerial application of DDT on reproduction in house wrens and mountain and western bluebirds. USDA For. Serv. Res. Pap. PNW-228, 22 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oregon.

No significant adverse effect on reproductive success of mountain bluebirds (*Sialia currucoides*), western bluebirds (*S. mexicana*), and house wrens (*Troglodytes aedon*) was detected after aerial application of DDT at a rate of 0.84 kilogram per hectare. The 2-year study determined the fate of 656 eggs within the spray area and 711 eggs within the control area.

KEYWORDS: Pesticide side effects, birds, mountain bluebirds, western bluebirds, house wrens, DDT, spraying (aerial).

RESEARCH SUMMARY

Research Paper PNW-228

1977

Observations of mountain bluebirds *(Sialia currucoides)*, western bluebirds *(S. mexicana)*, and house wrens *(Troglodytes aedon)* nesting in northeast Oregon were recorded for two breeding seasons after aerial applications of DDT at a rate of 0.84 kilogram per hectare (0.75 pound per acre). Numbers of eggs laid, eggs hatched, and young fledged from sprayed and control areas in 1974 and 1975 were compared. In 1975 additional data on weight gains and rate of nestling development were collected for mountain and western bluebirds. Population indices were made for flying insects in 1974 and 1975 and for ground dwelling insects in 1975 for sprayed and control areas. All statistical tests were examined for differences at the $P \leq 0.05$ level.

No significant differences between sprayed and control areas for clutch size, hatching success, or fledging success were observed for mountain bluebirds in 1974. There was a significant difference in clutch size for house wrens in 1974, but the difference was not attributed to DDT since spray application took place after eggs were laid. There was no significant differences in success in hatching or fledging between sprayed and control areas for house wrens in 1974.

Because of the small sample of western bluebird nests for sprayed areas, no statistical comparisions were made in 1974.

In 1975 there were no significant differences between clutch size for all three species in sprayed and control areas. There was no significant difference in success in hatching or fledging between sprayed and control areas for mountain bluebirds in 1975. There were differences for western bluebirds and house wrens.

No significant differences in mortality rates of nestlings were detected in either 1974 or 1975; only deaths that might have been caused by DDT were considered.

Comparisons of the three measures of reproduction between years for mountain bluebirds revealed significantly lower success in hatching and fledging in 1975. The difference was not attributed to DDT since success in hatching was greater in sprayed areas.

There were no observed differences in rates of nestling development or nestling weight gains for mountain or western bluebirds between sprayed and control areas. Unseasonal weather conditions and increased predation were believed to be the causes for lower success in hatching and fledging in 1975.

Introduction

This report is on an investigation of the effects of aerial applications of 0.84 kilogram per hectare (0.75 lb per acre) of technical grade DDT (dichlorodiphenyltrichloro-ethane) on success in reproduction of mountain bluebirds *(Sialia currucoides)*, western bluebirds *(S. mexicana)*, and house wrens *(Troglodytes aedon)*.

Extensive use of DDT after World War II resulted in widespread contamination of the biosphere (Dustman and Stickel 1966). Residues of DDT were recorded in thousands of species and in remote areas such as Antarctica (Tatton and Ruzicka 1967). DDT is a persistant chlorinated hydrocarbon that lasts an average of 4 years in the environment when it is applied at a rate of 0.56-0.84 kg/ha (0.5-0.75 lb/acre); applications of 1.8-2.3 kg/ha (4.0-5.0 lb/acre) may persist for 8-12 years (Kearney et al. 1969). In addition to its persistence, DDT or its metabolites are fat soluble, allowing them to accumulate and concentrate in fatty tissues of organisms (Macek 1970).

The immediate and most obvious effect of DDT on success in reproduction of avian populations is death of nestlings (Hotchkiss and Pough 1946, Adams et al. 1949, Mitchell et al. 1953, Wurster et al. 1965). Less obvious effects include reduced clutch size (Rubin et al. 1947), reduced success in hatching (Hickey and Anderson 1968, Heath et al. 1969), and reduced success in fledging (Ratcliffe 1965). Sex (Wurster 1969) and physical condition (Gish and Chura 1970, Stickel et al. 1965, Wurster 1969) were shown to be important variables influencing susceptibility to the toxic effects of DDT.

This research was initiated to explore the effects of aerial applications of DDT on bluebirds and house wren populations living in grasslands adjacent to forests treated for an outbreak of Douglas-fir tussock moth (*Orygia pseudotsugata* (McDunnough)). Measures of success in reproduction monitored during this study were clutch size, hatching success, and fledging success.

In addition, we examined certain insect populations to determine if any declines in insect biomass had occurred. Data on weight gains and development of nestlings were collected in 1975 as additional monitoring devices of available food supplies. Because little is known about insect food requirements of nestling bluebirds and house wrens, we felt that weight gain and development measurements might reflect a possible decline of certain important insect species that otherwise would not be detected.

Mountain bluebirds, western bluebirds, and house wrens were selected for study because they:

(a) are common summer residents of the grasslands included within the study areas (Gabrielson and Jewett 1940);

(b) are predominantly insectivorous during summer months (Martin et al. 1951; Beal 1915; Bent 1948, 1949; Knowlton and Harmston 1946);

(c) readily accept nest boxes (Headstrom 1970, Gabrielson and Jewett 1940);

(d) nest at 1-2 meters, (3.9-6.6 ft), allowing observations of nests and handling of their contents with minimum effort (Headstrom 1970, Powers 1966).

Study Areas

Two study areas were selected for placement of nest boxes (fig. 1): the La Grande unit, centered 15 km (9.3 mi) northeast of the city of La Grande, Union County, Oregon, and the Wallowa unit, centered approximately 20 km (12.4 mi) north of the city of Wallowa, Wallowa County, Oregon. Boxes in sprayed and control areas were located within the boundaries of the two units (fig. 1 and the appendix).

Areas for placement of nest boxes were selected from topographic maps and aerial photographs of the areas proposed for treatment. Criteria used in selection of study areas were:

1. Each area provided comparable amounts of nesting habitat for bluebirds and house wrens.

2. The areas had to be accessible by truck at least 6 months of the year.

3. Each area had to contain comparable numbers of the three study species.

These two areas were considered the population or populations. Any extension of results outside the condition of these areas would constitute extrapolation of the data. From

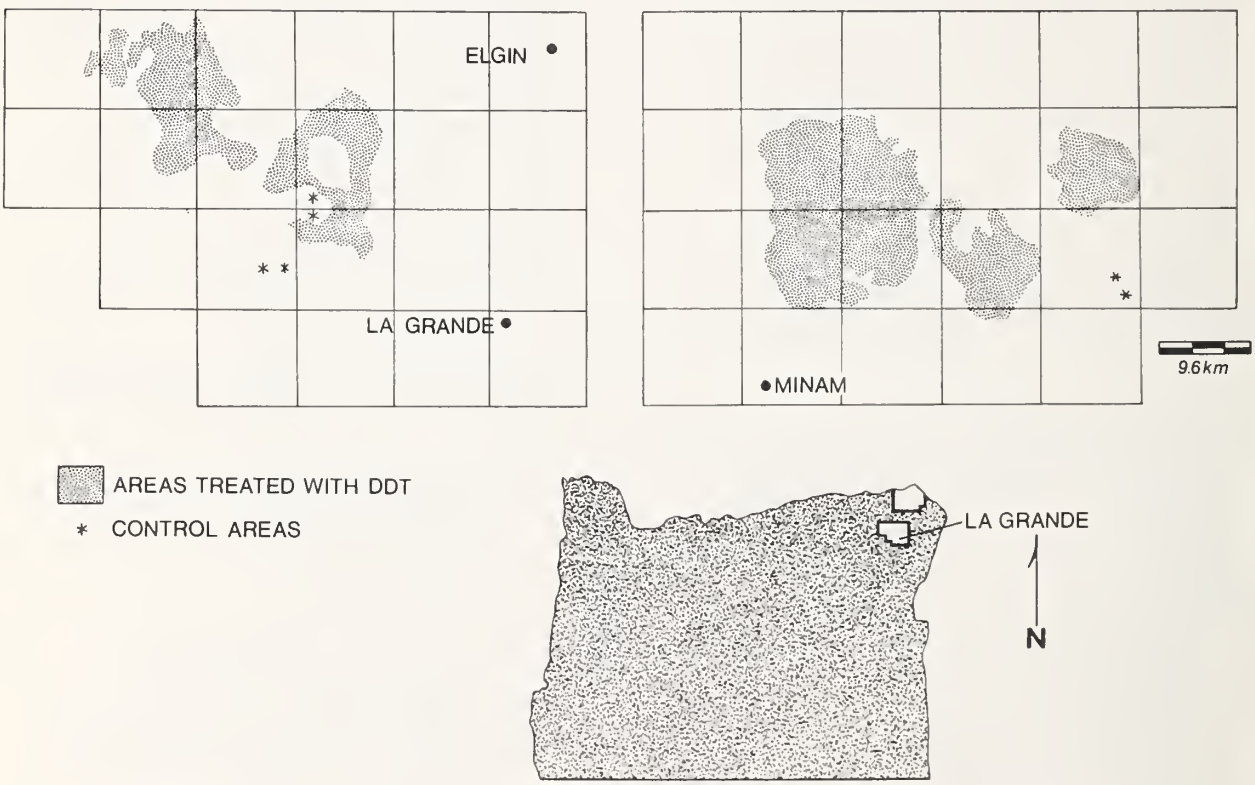

Figure 1.--Location of La Grande (left) and Wallowa (right) study areas in northeast Oregon, 1974-75.

pooled data sampled from each area, we assumed that the range in variation of these two areas was representative of the conditions to which we wished to draw inference. We further assumed that the samples of both treated and control areas were random, independent samples of these conditions.

Materials and Methods

A modification of bluebird nest boxes described by Schutz (1974) was used in the construction of 550 nest boxes.

In the spring of 1974, 250 nest boxes were placed in areas proposed for treatment; 300 boxes were placed as controls in proposed untreated areas. Changes in boundaries of the proposed spray areas before treatment, combined with low occupancy rates during the 1974 breeding season, led to relocation of 150 of 239 unused boxes from areas not sprayed to sprayed areas for the 1975 breeding season.

REPRODUCTION

Nest boxes were examined during the 1974 breeding season at 2- to 21-day intervals, In 1975, more personnel were available and nest boxes were examined at 2- to 6-day intervals. Boxes were opened on each visit and their contents examined.

Clutch size was defined as the number of eggs present at the onset of incubation. Differences between spray and nonspray areas were tested by means of a t-test (Snedecor and Cochran 1967).

We compared clutch size with the number of eggs hatched (proportion of eggs laid that hatched) to determine hatching success, and the number of young fledged with the number of young hatched (proportion of young hatched that fledged) to determine fledging success. Differences between spray and nonspray areas were examined by use of chi-square tests for independence (Snedecor and Cochran 1967). Because intervals between observations were 2-21 days in 1974 and 2-6 days in 1975, fledging numbers in many cases were derived circumstantially. Criteria used to determine fledging numbers were similar to those used by Powers (1966) in Montana: (a) age and condition of young at the previous examination; (b) a well-matted nest with an abundance of fecal material, indicating fledgling-age nestlings had been in the nest box; (c) absence of evidence of nest disturbance and/or predation.

WEIGHT GAINS

Data on nestling weight gains from the time of hatching to fledging were recorded so we could compare growth rates of nestlings living in sprayed and control areas in 1975. Nestlings from 8 mountain bluebird nests and 10 western bluebird nests from control areas and 20 mountain bluebird nests and 25 western bluebird nests from sprayed areas were weighed at 1-3 day intervals and compared by use of an F-test (Snedecor and Cochran 1967, p.125).

NESTLING DEVELOPMENT

To determine the effect on time of development of nestlings caused by the reduced insect food base, we compared the mean number of days to fledging for nestlings from 15 mountain bluebird nests and 10 western bluebird nests in control areas and 31 mountain bluebird nests and 24 western bluebird nests from sprayed areas. The t-test (Snedecor and Cochran 1967) was used to make these tests. No comparisons were made for house wrens because the small sample was further reduced by predators.

INSECT NUMBERS

To determine if there was a significant decline in density of insects, the dominant food item of bluebirds and house wrens, Butler (1965) obtained an index to numbers of flying insects in 1974 and 1975 from 13 malaise net traps. Seven traps were located in sprayed areas and six in control areas. Contents were collected at 3- to 8-day intervals. The air-dry weight of each sample was recorded and was used to calculate the rate of capture (weight per day) of insect biomass. The rate of decline in insect capture rates after DDT application in the spring was tested for significance by use of the F-test (Snedecor and Cochran 1967).

Numbers of grasshoppers were indexed during 1975 in the following manner. Ten 100-m (328-ft) transects were established in similar habitats in sprayed and control areas. Three 100-m (328-ft)-long sweeps with a 46.2-cm (18-in) diameter sweep net were made along each transect and the number of grasshoppers captured was recorded. Rates of capture between spray and nonspray areas were tested by use of the t-test (Snedecor and Cochran 1967).

NESTLING MORTALITY

Nestling mortality was recorded during each nest box check. If nestlings were missing before they reached fledging age, they were considered fatalities. The cause of death in each case was placed in one of two categories, "predation" or "other causes." Criteria used in determining deaths caused by predators were: (a) absence of prefledgling-age nestlings, (b) obvious signs of nest disturbance or destruction accompanied by dead or missing nestlings, and (c) remains of nestlings.

Nestling losses that did not fit the above criteria were placed in the category "other causes".

DDT APPLICATION

DDT reaching ground level was measured on three 10.2- by 12.7-cm (4- by 5-in) oil sensitive cards (White 1959) placed near each nest box. Because all three study species commonly nest at the forest edge adjacent to grasslands, we made simultaneous measurements of DDT applications at three different points for each nest box. One card was placed at the box, one card 20 m (65.6 ft) from the box in the adjacent clearing, and one card 20 m (65.6 ft) into the wooded area. Each card was stapled to a wooden stake and placed at ground level. The spray cards were placed in the field 12-24 hours before DDT was applied.

The spray cards were analyzed by a visual comparison of the number and size of spray droplets on each sample card with the standards for estimating airplane spray deposits on oil sensitive cards described by Maksymiuk (1963a) and Davis and Elliot (1953). The mean value of the three cards was considered the DDT level at that box.

Because of personnel shortages and logistics, the control areas were not monitored for DDT drift. Information gathered by other Forest Service personnel engaged in monitoring the spray application indicated that negligible spray drift was recorded 61 m (200 ft) from the spray boundaries and no spray was recorded 122 m (400 ft) from the spray boundaries. Control areas were therefore assumed to be uncontaminated by spray. This assumption was supported experimentally by T. Torgersen (personal communication), a

research entomologist with the Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon, who placed caged adult sarcophagid flies *(Agria housei)* in treated and untreated areas before the DDT applications. All of Torgersen's flies in treated areas died, but none of those in control areas, 400-800 m (1,312.3-2,624.6 ft) from the treated areas, died. It should be noted, however, that the study areas used had exposure to DDT prior to the 1974 applications. Between 1950 and 1955, the Forest Service sprayed DDT at a rate of 1.2 kg/ha (1.0 lb/acre) on six areas in northeast Oregon. These applications led eventually to total coverage of both control and treated areas. Because DDT persists for an average of 4 years in the environment when applied at 1.2 kg/ha (1.0 lb/acre), there was little chance that DDT residues from the 1950-55 spray projects would still be available for ingestion by bluebirds or house wrens (Kearney et al. 1969).

STATISTICAL TESTS—LEVELS OF SIGNIFICANCE

All statistical tests were evaluated with $P \leq 0.05$ as the criterion for acceptance or rejection of hypotheses.

Results

DDT LEVELS IN SPRAYED AREAS

The average amount of DDT recorded at ground level was 0.081 kg/ha (0.072 lb/acre) at the nest box, 0.075 kg/ha (0.067 lb/acre) in the forest, and 0.175 kg/ha (0.156 lb/acre) in the open (table 1). Data from 419 additional cards, from U.S. Forest Service monitoring teams, placed in a stratified manner across treated areas revealed an average of 0.202 kg/ha (0.18 lb/acre) at ground level.

The reasons for the large difference between the applied

Table 1--*DDT reaching ground level at four locations around nest boxes in sprayed areas, northeast Oregon, 1974*[1/]

Location[2/]	Forest[3/]	Nest Box	Open[4/]
		Kilogram per hectare	
Powatka	0.126	0.088	0.153
McAllister	.062	.072	.233
Horseshoe	.064	.071	.081
McAllister II	.051	.095	.273
Combined average	.075	.081	.175
Variance	.001	.001	.002

[1/] Application rate was 0.84 kilogram per hectare.

[2/] Location names refer to ridges where nest boxes were located.

[3/] 20 meters (66 feet) from nest box into forested area.

[4/] 20 meters (66 feet) from nest box into adjacent clearing.

rate and the rate measured on the ground were:

1. The surrounding vegetation (trees and shrubs) caused a screening effect (Maksymiuk 1963b).

2. DDT spray volatized before it reached ground level (Maksymiuk 1963b).

3. The helicopter pilots were instructed to shut off the spray when crossing grasslands larger than 0.81 ha (2 acres). Shut off and release of spray occurred at or very near actual box locations, which resulted in variable amounts of DDT reaching the ground around each box (Thomas and McCluskey 1974).

For additional details on sample sizes and standard deviations by spray area, see Thomas and McCluskey (1974).

INSECT RESPONSE TO DDT APPLICATIONS

The malaise traps captured only flying insects, which reportedly comprise a large portion of bluebirds' diet (Criddle 1927; Powers 1966, p. 361) but only a minor portion of the insect food for house wrens (Knowlton and Harmston 1946, Bent 1948). Although these traps have limitations when used for studying food supplies of bluebirds and house wrens, they were the most effective tool available when expense, time, and availability of personnel were considered.

Rates of capture for insects were measured in milligrams of biomass trapped per day. In 1974, the rate of capture generally declined on both sprayed and control areas prior to DDT applications (June 23-24)(fig. 2).

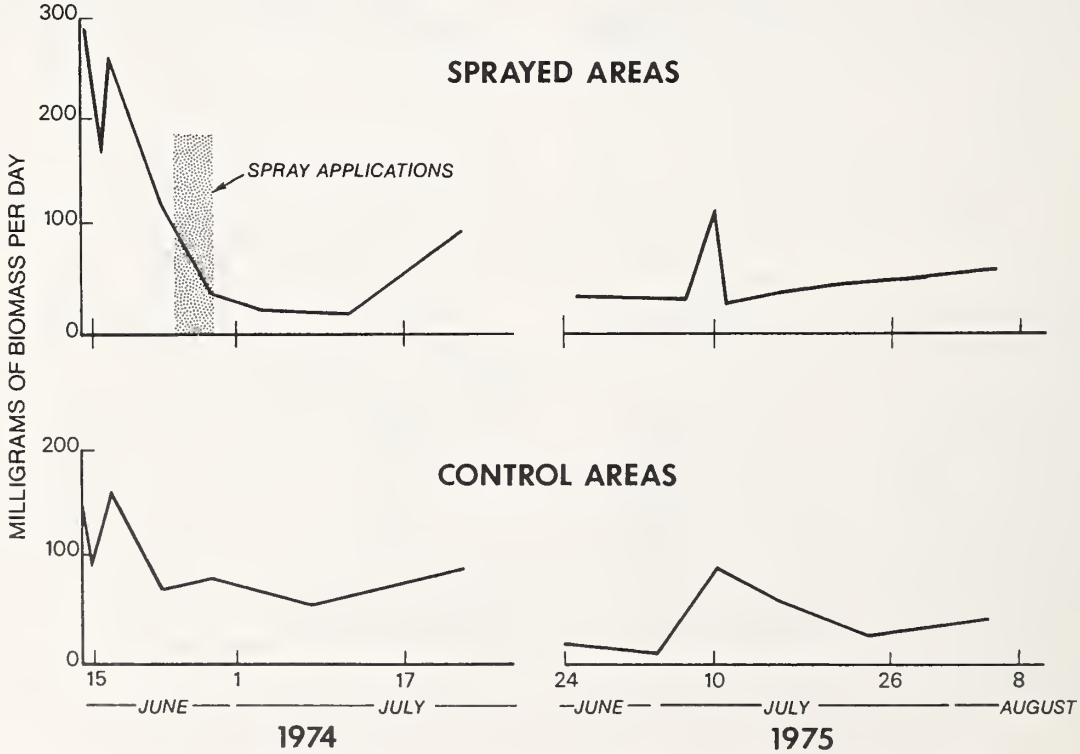

Figure 2.--Average rate of capture for flying insects in sprayed and control areas in northeast Oregon, 1974-75.

Insect capture rates, however, decreased significantly (d.f.=13, F=16.16) on treated areas immediately after DDT applications. Insect capture rates on sprayed areas declined by 80.7 percent compared with 41.9 percent on untreated areas.

Insect capture rates in 1975 were similar for both sprayed and control areas with no significant differences (d.f.=11, F=0.466) detected (fig. 2).

Grasshoppers collected in August 1975 served as an index to the abundance of ground dwelling insects. The mean number of grasshopper captures per transect was 5.1 (range 2-9) in sprayed areas and 4.9 (range 1-9) in control areas. A t-test indicated no significant differences (d.f.=18, t=0.190) in mean numbers captured between sprayed and control areas.

CLUTCH SIZE

Applications of DDT took place in 1974 after most egg clutches were laid; therefore, these applications of DDT could not affect clutch size. Likewise, DDT could affect hatching success in 1974 only if it altered adult behavior, caused adult mortality, or penetrated the eggshell (from pesticide materials on feathers of adults).

In 1974, a t-test indicated no significant difference (d.f.=57, t=0.584) in clutch sizes between sprayed and control areas for mountain bluebirds. There was a significant difference (d.f.=12, t=2.401) in mean clutch sizes for house wrens. Because there was only one western bluebird nest in sprayed areas, no statistical comparisons were made for this species.

During 1975, results were similar; for mean clutch sizes for the three species studied, there was no significant difference (d.f.=85, t=0.680 mountain bluebirds; d.f.=81, t=0.220 for western bluebirds; d.f.=5, t=0.398 for house wrens).

Data are displayed in table 2.

HATCHING SUCCESS

In 1974, hatching success was similar on sprayed and control areas. A chi-square test for independence (Snedecor and Cochran 1967, p. 125) revealed no significant differences (d.f.=1, X^2=0.65) in hatching success between sprayed and control areas for mountain bluebirds or house wrens.

A chi-square comparison of hatching success in 1975 between sprayed and control areas revealed no significant differences (d.f.=1, X^2=3.27) for mountain bluebirds. Comparisons between sprayed and control areas of hatching success for western bluebirds and house wrens did result in significant differences (d.f.=1, X^2=10.54 for western bluebirds; d.f.=1, X^2=4.36 for house wrens). Western bluebirds hatched an average of 4.3 eggs in sprayed areas and 3.6 in control areas. House wrens nesting in sprayed areas had an average hatch of 6.0, and birds in control areas hatched 4.0 eggs per clutch (table 2).

All eggs were treated as random, independent observations; that is, the degrees of freedom were computed on the basis of numbers of eggs, not on numbers of nests.

Table 2--*Clutch size, hatching, and fledging success for mountain bluebirds, western bluebirds, and house wrens nesting in both treated and untreated study areas in northeast Oregon, 1974-75*

Species	1974						1975					
	N (eggs)	Average clutch (number of eggs)	Average hatch (number of eggs)	Percent hatch	Average number fledged	Percent fledged	N (eggs)	Average clutch (number of eggs)	Average hatch (number of eggs)	Percent hatch	Average number fledged	Percent fledged
Mountain bluebird (sprayed)	63	5.3 (.16)	5.1	96.8	5.1	100	267	5.0 (.10)	4.2	83.1	3.2	75.2
Mountain bluebird (control)	246	5.2 (.10)	4.9	93.1	4.9	100	167	4.9 (.16)	3.7	76.0	2.6	69.3
Western bluebird (sprayed)	[2] 6	6.0	5.0	83.3	5.0	100	227	5.3 (.15)	4.3*	81.5	2.8*	65.9
Western bluebird (control)	44	4.9	4.9	100	4.9	100	213	5.3 (.15)	3.6*	68.1	2.1*	56.5
House wren (sprayed)	60	6.7* (.34)	5.9	88.3	5.9	100	33	6.6 (.51)	6.0*	90.9	4.0*	66.6
House wren (control)	27	5.4* (.50)	4.4	81.5	4.0	72.7	14	7.0 (1.0)	4.0*	57.1	1.5*	37.5

*Indicates significant differences ($P \leq 0.05$) between sprayed and control areas.

[1] Standard errors are in parentheses.

[2] Clutch sizes were not compared.

FLEDGING SUCCESS

Because DDT was applied on the study areas on June 23-25, 1974, the pesticide could have affected only survival of nestlings.

Fledging success for mountain and western bluebirds living on both sprayed and control areas in 1974 was 100 percent (table 2). House wrens nesting in sprayed areas averaged 5.9 young fledged per nest or 100 percent and those nesting in control areas averaged 4.0 young per nest for a success rate of 72.7 percent. The DDT applied had no deleterious effect on fledging success for the three species in the year of application.

In 1975, there were no significant (d.f.=1, X^2=1.45) differences in fledging success between sprayed and control areas for mountain bluebirds (table 2). Western bluebirds in sprayed areas fledged an average of 2.8 young per nest for 65.9 percent success compared with 2.1 young or 56.5 percent success in control areas. House wrens nesting in sprayed areas averaged 4.0 young fledged or 66.6 percent compared with 1.5 young per nest or 37.5 percent in control areas.

A chi-square test indicated that the greater fledging success exhibited by western bluebirds and house wrens from sprayed areas was significantly different from control area birds (d.f.=1, X^2=4.53 for western bluebirds; d.f.=1, X^2=4.36 for house wrens). These differences were in the wrong direction--i.e., mortality was greater in nonspray areas compared with spray areas. This

can be attributed to the substantial variations among treated and untreated areas.

NESTLING MORTALITY

There were no nestling mortalities reported for any of the three species in sprayed areas in 1974. Mortalities in the control area were limited to one complete brood of six wrens (Thomas and McCluskey 1974).

Nestling mortality was much higher in 1975 in both spray and control areas (table 3). Predation was the primary cause of these losses.

It seemed possible that deaths attributed to other causes (other than predation) might be related to DDT. To test this, we eliminated the losses from predation from consideration--i.e., we subtracted such losses from the total number of nestlings observed. The resulting figure is referred to as the adjusted total of nestlings observed. A ratio was then derived between the number of nestlings lost to other causes and the adjusted total of nestlings observed. This ratio was compared by bird species between spray and control areas.

No differences were detected between spray and control areas for mountain bluebirds (d.f.=1, $\underline{X}^2$=0.14), western bluebirds (d.f.=1, $\underline{X}^2$=3.35), and all species combined (d.f.= 1, $\underline{X}^2$=0.34). Chi-square tests were not possible for the data on house wrens due to occurrence of a zero for an expected value.

BETWEEN-YEAR COMPARISONS

Because tests indicated no statistical differences between sprayed and control areas in several measures of success in reproduction of mountain bluebirds in 1974 and 1975, we could have concluded that DDT had no effect on reproduction in this species. It could be argued, however, that lower rates of reproduction observed in 1975 than in 1974 were caused by DDT contamination. Therefore, we had to make between-year comparisons and test for differences in successful reproduction in 1975 (table 4).

Mountain bluebirds averaged 5.2 eggs per clutch in 1974 compared with 4.9 in 1975 (table 4). A $\underline{t}$-test indicated no significant

Table 3--*Nestling mortality in nonspray and spray areas*

Species	Nonspray areas					Spray areas				
	Total nestlings	Deaths			Survived to fledging	Total nestlings	Deaths			Survived to fledging
		Due to predators	Due to other causes	Total			Due to predators	Due to other causes	Total	
Mountain bluebirds	127	27	13	40	87	222	24	23	47	175
Western bluebirds	115	54	4	58	57	165	46	21	67	102
House wrens	8	5	0	5	3	56	5	2	7	49
Total	250	86	17	103	147	443	75	46	121	326

Table 4--*Comparison of combined sprayed and control area samples for mountain bluebirds, northeast Oregon, 1974 and 1975*

Year	N (eggs)	Average clutch (number of eggs)	Average hatch (number of eggs)	Percent hatch	Average number fledged	Percent fledged
1974	309	5.2	4.9	93.8	4.9	100.0
1975	434	4.9	4.0	82.3	2.9	73.1

differences (d.f.=144, $\underline{t}$=1.46) in clutch size between years for this species.

A comparison of hatching success for mountain bluebirds revealed 93.8 percent in 1974 and 82.3 percent in 1975, significantly lower (d.f.=1, $\underline{X}^2$=21.10) in 1975 than in 1974 according to a chi-square test.

Fledging success between years for mountain bluebirds declined from 100 percent (4.9 young per nest) in 1974 to 73.1 percent (2.9 young per nest) in 1975, a significant difference (d.f.=1, $\underline{X}^2$=90.87) as indicated by a chi-square test.

Some nest boxes were paired between years and some were not. We assumed that the samples at both times were independent random samples. Differences occurring between years could be attributed to either residual effect or yearly effect from climatic differences or both. These potential causes of differences are confounded and cannot be statistically reported.

RATE OF NESTLING DEVELOPMENT

We compared the average number of days to fledging for mountain bluebirds and western bluebirds nesting in sprayed areas and control areas in 1974 to determine if DDT applications affected nestling growth by reducing the insect food base. A $\underline{t}$-test comparison between sprayed and control areas indicated that the average number of days to fledging for mountain bluebirds and western bluebirds was not significantly different (table 5) (d.f.=35, $\underline{t}$=1.12 for mountain bluebirds; d.f.=35, $\underline{t}$=0.68 for western bluebirds).

Table 5--*Average number of days to fledging of nestling mountain and western bluebirds in sprayed and control areas in northeast Oregon, and 95-percent confidence interval, 1975*

Species	Sample size (nests)	Mean number days to fledging
Mountain bluebirds (sprayed area)	31	18.2 ± 0.60
Mountain bluebirds (control area)	15	17.5 ± 0.80
Western bluebirds (sprayed area)	24	19.3 ± 1.0
Western bluebirds (control area)	10	18.8 ± 0.90

Nestling Weight Gains

Mountain bluebirds and western bluebird nestlings of known age from sprayed and control areas were weighed at 1- to 4-day intervals in 1975 so we could document the rate of weight gain (table 6). An F-test comparison of mean daily nestling weights between sprayed and control areas for both species indicated no significant differences (d.f.=35, F=0.004 for mountain bluebirds; d.f.=35, F=0.008 for western bluebirds).

Table 6--*Mean body weights of nestling mountain bluebirds and western bluebirds in sprayed and control areas, northeast Oregon, 1975*[1/]

Age (days)	Sprayed areas						Control areas					
	Weight of mountain bluebirds	N	S^2	Weight of western bluebirds	N	S^2	Weight of mountain bluebirds	N	S^2	Weight of western bluebirds	N	S^2
	Grams			Grams			Grams			Grams		
1	3.1	9	0.38	2.9	14	0.10	3.1	2	0.05	2.5	4	0.50
2	4.4	5	.77	4.6	4	.27	5.1	3	.27	3.4	1	--
3	6.8	6	.22	5.2	3	4.33	7.3	1	--	6.0	3	1.50
4	10.1	6	9.15	9.6	8	1.41	10.5	3	1.81	8.4	3	2.65
5	14.2	5	7.74	10.7	6	7.06	14.0	1	--	11.7	3	4.95
6	15.6	2	10.62	14.8	7	8.66	16.3	3	4.56	14.2	3	2.93
7	17.9	9	9.98	16.2	9	5.62	19.3	1	--	16.3	2	4.05
8	23.4	5	11.83	19.9	7	.59	21.6	3	1.57	20.4	5	3.97
9	25.6	6	6.55	21.3	6	4.75	23.4	2	1.41	24.2	4	16.33
10	25.8	4	.24	23.3	6	5.57	27.2	2	13.60	24.3	2	7.50
11	28.0	4	2.36	23.3	4	6.18	26.0	2	2.50	24.8	3	4.95
12	28.7	10	3.06	26.7	6	1.82	27.4	4	9.83	25.5	3	5.25
13	29.1	4	2.04	27.1	5	7.78	28.0	1	--	26.5	3	4.75
14	28.3	4	1.10	27.0	4	1.51	30.3	1	--	26.6	3	.66
15	27.9	3	1.05	29.1	6	.62	28.4	2	.08	26.8	3	3.10
16	28.7	4	6.01	27.4	6	1.73	28.8	1	--	27.1	4	.56
17	28.5	2	.41	28.7	3	15.08	27.5	1	--	25.6	2	2.60
18	27.0	2	6.25	26.5	2	.50	28.0	1	--	25.1	2	1.30

[1/] 8 nests of mountain bluebirds and 10 nests of western bluebirds from control areas and 20 nests of mountain bluebirds and 25 nests of western bluebirds from sprayed areas.

Discussion

The application of DDT in 1974, after nearly all clutches were completed, could not have affected clutch size or egg viability for the three study species. It could have affected hatching success by altering adult survival or behavior.

The observed difference in clutch size for house wrens (table 2) was caused by predators' removing one or more eggs from each nest in control areas; this caused a loss of a greater proportion of the sample. There was no known nest predation in 1974, but more frequent observations in 1975 indicated that some egg losses to predators could have occurred with little or no obvious nest destruction.

If success in reproduction was affected by DDT in 1974, it would have had to be in terms of adult or nestling mortality. Because no dead adults or nestlings were observed on sprayed areas, fledging success was 100 percent (table 2).

Records of observations of mountain and western bluebirds 1 year after application of DDT were designed to disclose longer term impacts of DDT on success in reproduction.

Clutch sizes for all three species studied in 1975 were not

significantly different between sprayed and control areas, indicating that DDT apparently had not affected egg production.

The significant differences in hatching success between sprayed and control areas in 1975 for western bluebirds and house wrens probably were not caused by DDT because greater hatching success occurred in sprayed areas (table 2). Likewise, the significant differences in fledging success for western bluebirds and house wrens in 1975 were due to greater fledging success in sprayed areas than in control areas. It could be argued that the superior success in reproduction shown in nests in sprayed areas may have been the result of a DDT enhancement effect (Heath et al. 1969). If, however, this was the case, then fledging success for birds in sprayed areas in 1974 should also have been enhanced since this was the period when low levels of DDT were most available. The observed significant difference in fledging success for house wrens in 1974 was caused by the loss of a complete brood from a control area and not by greater fledging success of birds in sprayed areas. The observed difference for house wrens and western bluebirds in 1975 was attributed to a type 1 error (Snedecor and Cochran 1967, p. 27). One entire house wren clutch of six eggs failed and five nestlings in the only remaining nest were preyed upon. This left only three nestlings to fledge from a sample of eight nestlings. The loss of 54 nestlings to predators in control areas compared with 48 in sprayed areas accounted for the observed difference in western bluebird fledging success. This is reasonable supportive evidence that the superior success in reproduction reported for house wrens in 1974-75 and western bluebirds in 1975 from sprayed areas was not caused by DDT enhancement.

ADULT AND NESTLING HOMING BEHAVIOR

For us to monitor impacts of DDT on reproduction of mountain and western bluebirds and house wrens 1 year after spray applications, the living adults and nestlings had to demonstrate reasonable fidelity for breeding areas each year. Fidelity to former breeding areas was not well documented for mountain bluebirds or western bluebirds. Passerine species in general, however, show a marked tendency to return to the same locality in successive breeding seasons (Farner 1945, Uchida 1932). Powers (1966, p. 364) determined that three (42.8 percent) of the adult mountain bluebirds banded during the 1st year of this study returned to breed on his 136-ha (336-acre) study area the following year. During the second year of banding, Powers (1966) observed that three (25 percent) banded adults returned to his study area. These included one adult female which returned to breed for the second consecutive year. Powers (1966, p. 364) commented:"...three of the five returning adults, one male and two females, nested in the boxes they had previously occupied, and the others nested very close to their former nesting territories indicating strong fidelity to the nesting area." Several investigators (Laskey 1940, Krug 1941, Thomas 1946) determined that the number of adult eastern bluebirds returning to former breeding areas ranged between 36 and 60 percent. This figure would actually represent a larger percentage of the number of

birds still available 1 year later if corrections for annual mortality were made. Annual mortality is generally in excess of 50 percent of the adult population (Lack 1954).

Homing for birds banded as nestlings is generally less precise than for adults, but returns to the same general area can be expected (Nice 1937). Observations on starlings *(Sturnus vulgaris)* (Kluijver 1933), tree swallows *(Iridoprocne bicolor)* (Low 1934), barn swallows *(Hirundo rustica)* (Uchida 1932), and song sparrows *(Melospiza melodia)* (Nice 1937, p. 189) indicated that 1.5-12.6 percent of the birds banded as nestlings returned to former nesting areas to breed. Farner (1945) and Hickey (1943) concluded that homing for 1st-year-breeding robins *(Turdus migratorius)*, a species closely related to bluebirds, was definitely not random, but that 70-74 percent of the surviving young returned to breed within a 16- to 40-km (10- to 25-mi) radius of the place where they hatched. Similar data were reported for bank swallows *(Riparia riparia)* and song sparrows (Bergstrom 1951, Nice 1937).

Homing for house wrens was thoroughly studied by Kendeigh (1941). He estimated that 19 percent of the birds banded as adults returned to breed 1 year later and that 10 percent of the birds banded as nestlings returned to breed within 3.2-km (2-mi) radius of their natal nest.

These banding figures were based on the number of young banded with no adjustments for annual mortality which may be as high as 75 percent (Ricklefs 1973). Although specific data on fidelity to nest site is lacking for bluebirds banded as nestlings, the information available on other related species as well as on adult bluebirds indicates that 1st-year-breeding bluebirds would demonstrate reasonable nest-site fidelity. Therefore, the birds observed breeding on study areas in 1975 were likely either adults that nested in the same areas in 1974 or nestlings reared in the areas in 1974.

BETWEEN-YEAR COMPARISONS

The significant difference in hatching success between years for mountain bluebirds probably was not caused by DDT since hatching success was greater in sprayed areas rather than in control areas. The reason for the difference in hatching success between years is not known. Observed hatching rates in 1975 possibly were significantly lower because of increased bird densities in both sprayed and control areas. White and Wolfenden (1973) observed significantly lower occupancy rates for eastern bluebirds but greater success in reproduction the 1st year nest boxes were erected than the 2d year. They felt that the decline in reproduction observed the 2d year of their study could be attributed to greater social pressure resulting from increased density. Information from this and other studies indicates that hatching success in 1975 was usually greater for all three species than was previously reported (table 7). The 11.5-percent difference in hatching success observed between years for mountain bluebirds in this

Table 7--*Data on reproduction from nest box studies of mountain bluebirds, western bluebirds, and house wrens*

Author	Species	Sample (eggs)	Average clutch (number of eggs)	Average hatch (number of eggs)	Percent hatched	Average number fledged	Percent fledged
Powers (1966)	Mountain bluebird	104	4.9	3.8	76.9	2.9	76.3
Miller (1970)	Mountain bluebird	106	4.8	3.3	67.0	2.8	88.1
Prigge (1975)	Western bluebird	481	5.1	3.3	65.3	2.5	74.2
Kendeigh (1941)	House wren	6,773	6.4	5.3	82.3	4.2	79.0

study was, considerably lower than the 32.4-percent between-year difference observed by Powers (1966, p. 359). It is not unreasonable, therefore, to attribute the difference in hatching success between 1974 and 1975 to between-year variation.

Weather also may have been an important factor affecting hatching success in 1975. A comparison of weather conditions for June, the principal month of clutch establishment and hatching for the three species, indicated that June 1975 was colder and wetter than June 1974 (table 8). Data collected at Meacham, Umatilla County, Oregon, an area representative of the study areas, indicated that the mean monthly temperature for June 1974 was 1.4°C (2.5°F) lower than the 30-year average and precipitation was 0.97 cm (0.4 in) above normal (table 8). Reports by Criddle (1927), Musselman (1939), Miller (1970), and Pinkowski (1975) revealed that cold-wet weather conditions often caused adult female bluebirds to leave their eggs for long periods, resulting in partial or total failure of the eggs in those nests to hatch. Scott and Lane (1974) reported that 80 percent of the first nests of mountain bluebirds

Table 8--*Average monthly temperature and precipitation for June 1974-75 and 30-year average (1940-70), Meacham, Oregon*[1/]

Year	Monthly average temperature	Monthly average precipitation
	Degrees Celsius	Centimeters
1974	15.2	4.47
1975	11.0	6.35
30-year average, 1940-70	12.4	5.38

[1/] Data derived from National Oceanic and Atmospheric Administration, Meacham, Oregon, station.

failed after a 2-day period when mean daily temperatures of 7.2°C (45°F) and 12.7°C (55°F) were accompanied by 4.4 cm (1.7 in) of precipitation.

Adverse weather conditions and predation were considered responsible for the lower fledging success in 1975.

Mortality resulting from colder than normal weather between June 15 and June 29, 1975 is evident in figure 3. Of 60 nestlings lost to causes other than predation, 53 or 84.1 percent died when mean daily temperatures were below the 30-year average for that day (fig. 4). A period of below-normal temperatures coincided with hatching of the eggs in the majority of nests on the study areas and probably increased the severity of the weather effect. Passerine young are most susceptible to adverse weather conditions until they are 9-10 days old (O'Connor 1975). Scott and Lane (1974) noted that nearly all the dead nestlings they discovered after a severe storm were 1-7 days old. Lane and Burton (1974) and Scott (1974) determined that severe weather conditions reduced the number of young fledged per nest by as much as 50-83 percent.

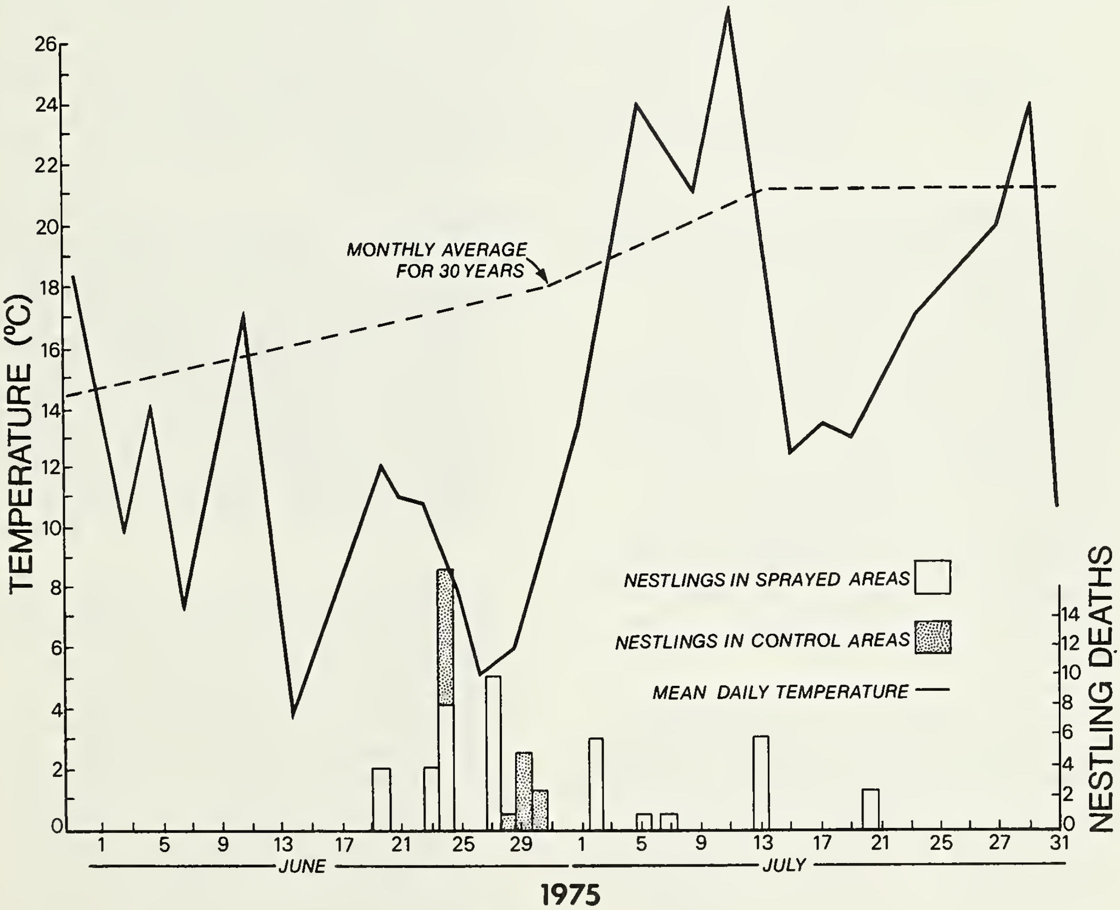

Figure 3.--Average daily temperature, 30-year monthly average temperature, and combined nestling mortality from sprayed and control areas in northeast Oregon, 1975.

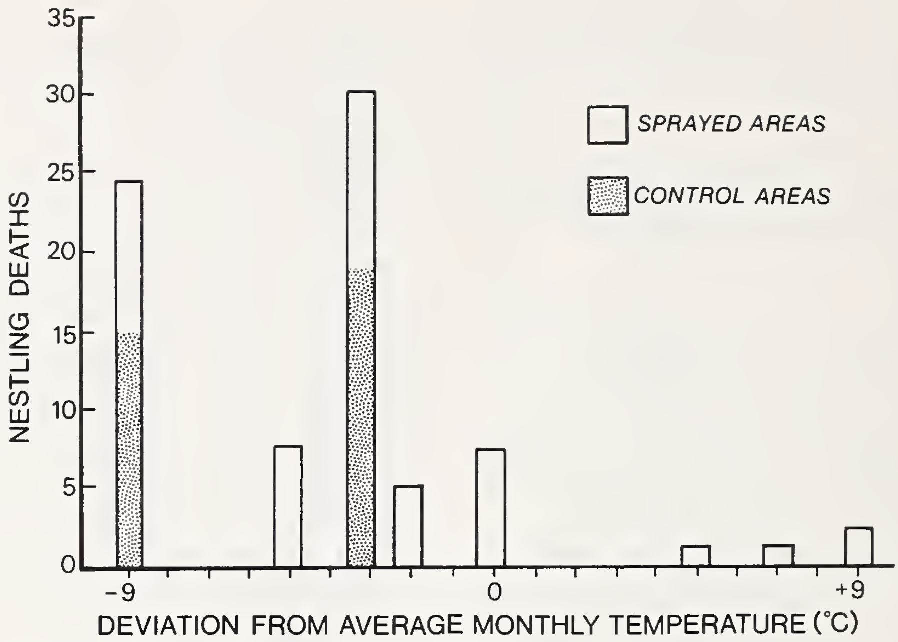

Figure 4.--Mortality of bluebird and house wren nestlings in northeast Oregon in 1975 in relation to the deviation of the daily average temperature for June and July from the 30-year average temperature.

Predation was a major cause for the decline in fledging success for all three species in 1975 (table 3). Fifty-one nestlings or 59 percent of all mortality that occurred for mountain bluebirds was caused by predators. Western bluebird losses were greater, with a loss of 100 nestlings or 82 percent of all mortality attributable to predation. House wren mortality attributable to predation accounted for 10 nestlings or 83 percent of the nestlings that died.

The cause of increased predation in 1975 was attributed to more frequent examinations of the nests and their contents and to a larger available sample of occupied nest boxes. Examination of nest boxes at more frequent intervals (2-6 days) in 1975 often caused considerable disturbance of adult birds around the nest. Wilson (1966) determine that the low nesting success for 17 bird species he studied was caused by frequent human activity around the nests. Studies of nest predation in waterfowl indicated that many predators were able to locate nests by movements of adult birds around the nest site (Hammond and Forward 1956).

Three mammal species observed preying on bluebirds and house wrens during this study were the yellow pine chipmunk *(Eutamius amoenus)*, red squirrel *(Tamiasciurus hudsonicus)*, and weasels *(Mustela frenata, M. erminae)*. It was not known if weasels could recognize nest boxes as a source of food or if nest disturbances by the observers allowed weasels to locate nests more easily. In several cases, two or three occupied nest

boxes in sequence were preyed upon, indicating that the weasels may have associated the nest box with food and learned to search them systematically.

Egg and nestling losses attributed to squirrels and chipmunks appeared to be related to cavity investigation for possible nest sites. Subsequent observations on destroyed nests revealed that many had additional nesting material added to the box by squirrels and chipmunks. In several cases sciurid litters were reared in nest boxes.

Based on the methods used, the results of this study indicated that DDT applied at 0.84 kg/ha (0.75 lb/acre) had neither an immediate effect on nestling survival nor a 2d-year impact on clutch size, hatching, or fledging success for mountain bluebirds, western bluebirds, and house wrens. These results should not, however, be used to assign DDT a role as a harmless contaminant in our environment. Applications of DDT at dosage levels which apparently did not disrupt success in reproduction of bluebirds and house wrens still contribute to DDT residue in the environment and can be passed on through the food web.

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Appendix

LEGAL DESCRIPTION OF RIDGES WHERE SPRAY AND CONTROL AREA BOXES WERE LOCATED

Ridge	Township	Range	Sections
Spray areas:			
Horseshoe I	1 N	36 E	7, 18, 19, 20
Horseshoe II	1 N	35 E	3, 10, 11, 13, 14
Powatka	3 N	43 E	9, 12, 22, 27, 32, 33
McAllister I	3 N	44 E	18, 19, 30, 31
McAllister II	2 N	44 E	6
McAllister II	2 N	43 E	1, 12, 13, 24, 25, 36
Control areas:			
Fox Prairie	1 S	36 E	35, 36
Y-Ridge	2 S	37 E	5, 6
Interstate 80 N	2 S	36 E	21, 27, 28
Spring Creek	2 S	36 E	27, 34
Sled Springs	3 N	44 E	35, 36
Starvation Ridge	2 N	44 E	13, 24, 25

GPO 985-159

McCluskey, D. Calvin, Jack Ward Thomas, and E. Charles Meslow. 1977. Effects of aerial application of DDT on reproduction in house wrens and mountain and western bluebirds. USDA For. Serv. Res. Pap. PNW-228, 22 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

No significant adverse effect on reproductive success of mountain bluebirds *(Sialia currucoides)*, western bluebirds *(S. mexicana)*, and house wrens *(Troglodytes aedon)* was detected after aerial application of DDT at a rate of 0.84 kilogram per hectare. The 2-year study determined the fate of 656 eggs within the spray area and 711 eggs within the control area.

KEYWORDS: Pesticide side effects, birds, mountain bluebirds, western bluebirds, house wrens, DDT, spraying (aerial).

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